B hadron production and inclusive b decays at LEP

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508: B hadron production and inclusive b decays at LEP

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Abstract. The production of beauty particles at LEP is reviewed. The results of inclusive studies are then presented, with an emphasis on semileptonic decays and studies of the number of charm in b decays.

1 B hadron production

Beauty quarks are produced at LEP through $e^+e^- \to Z^0 \to b\bar{b}$. These quarks can produce B^+, B_d^0, B_s^0 and beauty baryons through hadronization. In this section, the latest measurements of the production rates are reviewed.

From the studies of $\Lambda_c^+ - l^-$ and $\Xi^- - l^-$ correlations [1], the fraction of b quarks which hadronize into beauty baryons is estimated to be $(10.6^{+3.7}_{-2.7})\%$. The ALEPH Collaboration presents the results of a new analysis [2] based on the study of inclusive proton production in b tagged events : $f_{b-baryon} = (12.1 \pm 0.9(stat.) \pm 3.1(syst.))\%$. The average of the two values quoted above is $(11.3^{+2.5}_{-2.1})\%$.

From the studies of D_s-lepton correlations and of the mixing parameter $\chi = f_{B_d^0}\chi_d + f_{B_s^0}\chi_s$, the LEP B Oscillation Working Group [1] obtains the fraction of b quarks which hadronize into a B_s^0 meson : $f_{B_s^0} = (10.3^{+1.6}_{-1.5})\%$. The DELPHI Collaboration presents preliminary results of a new analysis [3] based on the study of the correlation between the charge of the produced quark (determined by a neural network) and the charge of the kaon which can be produced at the primary vertex when a B_s^0 is produced : $f_{B_s^0 + B_s^{**}} = (14.4 \pm 1.7(stat.) \pm 3.0(syst.))\%$. With some assumption on the fraction of charged beauty baryons (e.g. $f_{B_s^{**}}/(f_{B_s^0} + f_{B_s^{**}}) = 0.25 \pm 0.05$), the average value of $f_{B_s^0}$ is found to be $(10.4^{+1.4}_{-1.3})\%$.

Using the averages quoted above, assuming isospin symmetry ($f_{B^+} = f_{B_d^0}$) and the closure relation $\Sigma f_{b-species} = 1$, the fraction of beauty quarks hadronizing into a B^+ or a B_d^0 is then found to be $f_{B^+} = f_{B_d^0} = (39.15^{+1.2}_{-1.4})\%$.

The DELPHI Collaboration also presents the first measurements of the fraction of b quarks hadronizing into a charged or a neutral b hadron [3]. From a study of secondary vertex charge, DELPHI gives : $f_{H_B^0} = (57.8 \pm 0.5(stat.) \pm (1.0))\%$, and $f_{H_B^\pm} = (42.2 \pm 0.5(stat.) \pm (1.0))\%$. These results are consistent with the numbers quoted above, yet the systematic errors are very preliminary and some assumption on the fraction of charged b baryons is needed to extract usefull information from these measurements.

2 Charged multiplicity of weakly decaying B hadrons

New inclusive analysis have been developped by the LEP Collaborations to study b decays. A crucial parameter in such inclusive studies is the charged multiplicity of weakly decaying B hadrons (n_B): it is used (and needed) in particular to control the agreement between data and simulation.

The DELPHI Collaboration presents a new preliminary measurement of n_B, based on the study of positive and negative impact parameter distributions of tracks in b-jets [4]. DELPHI obtains $n_b = 4.96 \pm 0.03(stat.) \pm 0.05(syst.)$, which is much more precise than the older results of OPAL (obtained in 1994 with a systematical error of 0.49) and the previous results of DELPHI (obtained in 1995, with a systematical error of 0.38).

3 Semileptonic b decays

Among all the branching ratios of beauty particles, the semileptonic branching ratio is important for the estimation of the CKM matrix element V_{bc}, or to control the systematic in the measurements of the branching fraction of the Z^0 into $b\bar{b}$.

DELPHI is the only LEP Collaboration which gives an update of inclusive semileptonic branching ratios, from a re-analysis of 1994 data using a fit to momentum and transverse momentum distributions of leptons in b-tagged events containing one or two leptons [5]. The LEP averages provided by the LEP ElectroWeak Working Group [6] are $Br(b \to l) = (11.12 \pm 0.20)\%$ and $Br(b \to c \to l) = (8.04 \pm 0.33)\%$. The LEP average for $Br(b \to l)$, once noticed the presence of b-baryons and B_s^0 at LEP, is still surprisingly higher than the value obtained by CLEO at lower energy $((10.49 \pm 0.046)\%)$ [7].

The DELPHI and ALEPH Collaborations also presented some specific studies of these semileptonic decays. Using a neural network based on inclusive vertex charge, DELPHI obtains the first estimations of the semileptonic branching ratios of the B^+ meson [8]: $Br(B^+ \to l^+) = 0.136 \pm 0.008$ and $Br(B^+ \to l^-) = 0.060 \pm 0.006$, where the errors are statistical only. From the study of proton-lepton correlations in b-tagged events, ALEPH [2] gives $Br(b - baryon \to pl^- X)/Br(b - baryon \to pX) = (7.8 \pm 1.2(stat.)) \pm 1.4(syst.))\%$, which is compatible with an older OPAL result [9]. The semileptonic branching ratio of beauty baryons is then found to be lower than the semileptonic branching ratio of beauty mesons, which is consistent with the ratio of baryon/meson lifetimes.

It is then interesting to study the semi-exclusive modes of semileptonic b decays in order to compare the inclusive $b \to l$ result to the sum of its exclusive components. The DELPHI Collaboration presents a new preliminary measurement of the production of orbitally excited D^{**} in semileptonic b decays [10]. From a study of inclusive D^* production and a fit to the missing mass squared, DELPHI gives $f^{**} = 0.19 \pm 0.09$. Averaging this value with a result presented by ALEPH in 1996 [11], and taking into account D-lepton, D^*-lepton [12] and X_u-lepton [13] production, the exclusive results sum up to $(85 \pm 8)\%$ of the inclusive LEP value for $Br(b \rightarrow l)$, which shows that there is no serious discrepancy in this sector.

4 Charm in b decays

The b semileptonic branching ratio ($Br(b \rightarrow l)$) and the number of charm in b decays (n_c) should obviously be anti-correlated.

The number of charm in b decays can be estimated using $n_c = 1 + f(B \rightarrow D\overline{D}) + f(B \rightarrow$ *"hidden"* $c\bar{c}) - f(B \rightarrow$ *no c*), where the *"hidden"* $c\bar{c}$ is the contribution of bound states (e.g. J/ψ). The DELPHI Collaboration gives a new preliminary result for the *"open charm"* term : $f(B \rightarrow D\overline{D}) = 0.166 \pm 0.036$. This result is obtained from an average of two results [14], one coming from the inclusive study of the distribution of a b-tagging probability variable, the other coming from the study of the transverse momentum distributions of kaons in b-tagged events containing two kaons. Using some assumptions or CLEO measurements for the *"hidden charm"* and *"no charm"* contributions [15], DELPHI obtains $n_c = 1.166 \pm 0.038$, which is compatible with the last CLEO result (1.10 ± 0.05) [16] or the results coming from charm counting at LEP (errors of 0.08) [17].

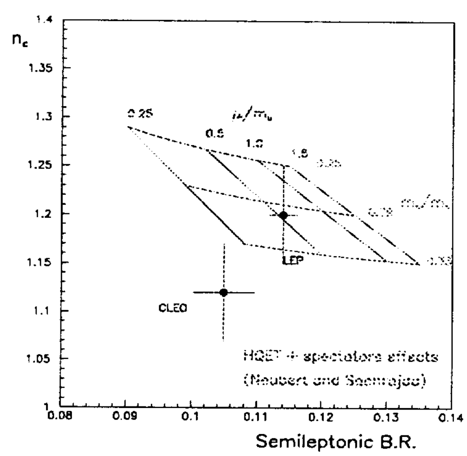

Fig. 1. Measurements of the number of charm in b decays vs the semileptonic branching ratio. The curves indicates theoretical expectations, the dots correspond to the LEP and CLEO data. The LEP point has been corrected by the ratio of meson/baryon lifetimes to account for baryon production at LEP.

The $Br(b \to l)$ and n_c results obtained at LEP and at lower energy (CLEO) may show some discrepancy. The values obtained at LEP are consistent with the HQET expectations [18] but the semileptonic branching ratio obtained at LEP is quite higher than the one obtained by CLEO (the LEP point has been corrected for the baryon production effect on Figure 1). The discrepancy between the two values of n_c is quite small, yet both $Br(b \to l)$ and n_c are found at high values at LEP. Some dedicated effort on this problem at LEP and by CLEO could clear the situation.

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